

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

MODULE TEST

TRIMESTER 3, 2020/2021

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY (EE)

MAY AND JUNE 2021
Continuous Assessment
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 6 and 7 for a list of physical constants, formulas, and the error function table.

MODULE TEST 1

- (a) Explain the Czochralski (Cz) single crystal growth process. Describe the shortcomings of the Cz crystal growth technique. [12 marks]
- (b) Describe the processing steps in transforming the silicon (Si) ingot grown using Cz technique, into the thin sheet of Si wafers. [4 marks]
- (c) In a Cz growth process, a Si boule is pulled from the melt mixed with Si and Boron (B) dopant. The Si ingot is then sliced into thin wafers. The wafer taken from the top of the boule has an B concentration of $5 \times 10^{17} \text{ cm}^{-3}$. The segregation coefficient (k) for the B is given as 0.8. Determine the doping concentration of the Si wafer taken from the position corresponding to 55 % of the initial charge solidified. Identify the conductivity type of these Si wafers. [3+1 marks]

Continued

MODULE TEST 2

The silicon-based silicon-on-insulator-bipolar junction transistor (SOI-BJT) technology is a promising candidate for realizing future Radio Frequency System-on-Chip (RFSoc) applications. A schematic cross-section of a BJT on SOI substrate is given in Figure 2.

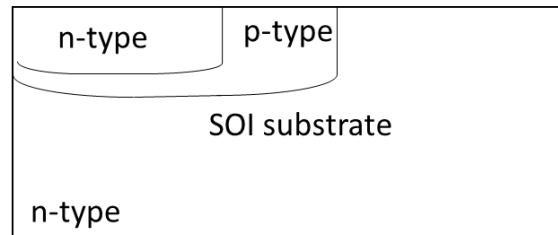


Figure 2: Schematic cross-section of a BJT on SOI substrate.

- (a) Design a photolithography fabrication process flow for the SOI-BJT given in Figure 2. Illustrate each processing step, starting from the N-type silicon wafer. How many masking levels are involved in the fabrication process of the SOI-BJT? [12+2 marks]

- (b) Photoresists (PR) are polymeric materials that transfer micro or nanostructured patterns to a substrate through a radiation-induced solubility change. Compliment the performances of the positive PR and negative PR given in Table 2(b). [4 marks]

Table 2(b)

Performance	Negative PR	Positive PR
Etch resistance		
Step coverage		
Adhesion		
Exposure speed		

- (c) Photolithographic patterning process is deployed in the device processing for SOI-BJT in Figure 2 using contact printing approach with exposure wavelength of 247 nm. If the photoresist thickness is 1.2 μm and the photoresist constant, k , is given as 0.68, determine the minimum feature size, W_{\min} , that can be achieved using the contact printer. [2 marks]
- (d) Design an etching solution for the device patterning for the SOI-BJT given in Figure 2, based on the best resolution achievable by deploying the contact printer described in Question 2(c). Describe the distinctive performances of your proposed etching solution. [4 marks]
- (e) Propose a solution to functionalize the SOI-BJT given in Figure 2. Describe the formation process for the proposed solution. [6 marks]

Continued

MODULE TEST 3

- (a) In your design for SOI-BJT given in Figure 2, propose a doping technique for the SOI-BJT n-well and p-well structures, which prioritizes the costing and simplicity of the equipment setup. Describe the limitation for proposed doping scheme, and design an implementation strategy that can effectively accomplish the n-well and p-well in a timely manner through this proposed doping technique.

[2+2+4 marks]

- (b) In your design in Figure 2, in order to form the p-well, boron is diffused into the n-type silicon (Si) wafer with a background doping concentration of $1.5 \times 10^{17} \text{ cm}^{-3}$. The diffusion process is performed at 1050°C for 50 minutes and the boron concentration at the surface is held at $1.5 \times 10^{19} \text{ cm}^{-3}$. The diffusion coefficient for boron at 1050°C is given by $1.5 \times 10^{-15} \text{ cm}^2\text{s}^{-1}$. Calculate the junction depth of the p-well in the SOI-BJT following the boron diffusion process. Is this pre-deposition diffusion or drive-in diffusion?

[7+1 marks]

- (c) As an alternative technology to diffusion, ion implantation is adopted. In an ion implantation process, a 250 keV implant of boron is performed onto a wafer. The projected range of the implanted profile is 4000 \AA . Take the standard deviation of the projected range as 550 \AA .

- (i) Determine the depth of peak of the implanted profile. [1 mark]
(ii) Calculate the peak concentration for dose of $2 \times 10^{17} \text{ cm}^{-2}$. [3 marks]

Continued

MODULE TEST 4

- (a) Describe the process flows of the semiconductor IC production upon the completion of the front-end processes; deposition, doping, patterning, metallization, and oxidation processes. [5 marks]
- (b) To evaluate if the semiconductor devices produced conform to device specifications, various tests are required. Identify these tests and briefly describe the respective function of these tests. [8 marks]
- (c) There are two principal methods available for die attachment, namely epoxy die attachment and eutectic die attachment. Describe how do epoxy and eutectic die attachment work? Evaluate the following scenarios, and decide the suitable die attachment method for the respective scenario. [4+5 marks]
- (i) The dice that easily get heated up during operation.
 - (ii) IC production throughput needs to be high.
 - (iii) Low cost die attachment process is needed.
 - (iv) Less complicated machinery tools are preferred.
 - (v) The dice that need to be electrically contacted to the IC package in densely packed circuits.
- (d) Based on your evaluation on following integrated circuit (IC) operating power ranges, determine the suitable packaging technology for the ICs. [2 marks]
- (i) IC with total power dissipation below 1 Watt
 - (ii) IC with total power dissipation up to 5 Watt
- (e) A 500 mm wafer has a defect density of 30 defects/cm². Each die on the wafer has a size of 2×2 mm². Assuming uniform defect density, determine the minimum market price for each die if the cost for testing and packaging each die is RM 1.00, while the total fabrication cost is RM 5000. [6 marks]

Continued

APPENDIX**Physical Constants:**

Avogadro number, $N_{\text{avo}} = 6.02217 \times 10^{23} \text{ mol}^{-1}$

Boltzmann constant, $k = 1.380622 \times 10^{-23} \text{ J K}^{-1} = 8.61712 \times 10^{-5} \text{ eV K}^{-1}$

Electronic charge, $e = 1.60219 \times 10^{-19} \text{ C}$

Electron rest mass, $m_0 = 9.10956 \times 10^{-31} \text{ kg}$

Electron volt, $1 \text{ eV} = 1.60219 \times 10^{-19} \text{ J}$

Si yield strength = $2 \times 10^7 \text{ dynes cm} = 7 \text{ GPa}$

Latent heat of fusion for Si, $L = 340 \text{ cal g}^{-1}$

Thermal conductivity of Si, $k = 0.21 \text{ W cm}^{-1} \text{ }^\circ\text{C}^{-1}$

Amount of heat of 1 calorie = 4.14 J

Density of bulk Si = 2.33 g cm^{-3}

Density of molten Si = 2.53 g cm^{-3}

Electric current of 1 A = 1 Cs^{-1}

Atomic mass unit of 1 amu = $1.66053 \times 10^{-27} \text{ kg}$

Magnetic flux density of 1 T = $1 \text{ Wb m}^{-2} = 10^4 \text{ G}$

Angstrom unit of $1 \text{ \AA} = 1 \times 10^{-10} \text{ m} = 0.1 \text{ nm} = 1 \times 10^{-4} \text{ }\mu\text{m}$

Permittivity of free space = $8.85 \times 10^{-14} \text{ F cm}^{-1}$

Pressure of 1 Torr = 133.32237 Pa

Formulas:

$C = kC_o(1 - x)^{k-1}$	$C_s = \frac{Q_T}{\sqrt{\pi Dt}}$
$\sigma = pq\mu$	$N(x) = \frac{Q_o}{\sqrt{2\pi\Delta R_p}} e^{\left[\frac{-1}{2}\left(\frac{x-R_p}{\Delta R_p}\right)^2\right]}$
$W_{min} = \sqrt{k\lambda g}$ $W_{min} = K\{\lambda/NA\}$	$N(R_p) = \frac{Q_o}{\sqrt{2\pi\Delta R_p}}$
$C(x, t) = C_s \operatorname{erfc}\left[\frac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\frac{1 - e^{-D_o A}}{D_o A}\right]^2$
$Q = 2C_s \sqrt{\frac{Dt}{\pi}}$	$Y = \left[\frac{1 - e^{-2D_o A}}{2D_o A}\right]$
$C(x, t) = \frac{Q_T}{\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$	$N = \frac{\pi(r - S)^2}{S^2}$
$x_j = 2\sqrt{Dt \ln \frac{C_s}{C_b}}$	$Y = e^{-D_o A}$
$x_j = 2\sqrt{Dt \ln(N_o/N_b)}$	$x_j = 2\sqrt{Dt} \operatorname{erfc}^{-1}(N_b/N_o)$

Continued

Values of the error function $\text{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\text{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi} t} \exp(-t^2)$

$\text{erfc}(t) = 1 - \text{erf}(t)$

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